Assignment 2

# Queuing System Simulation

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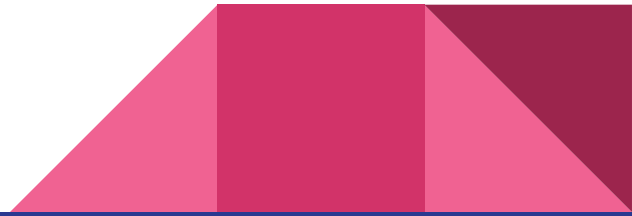
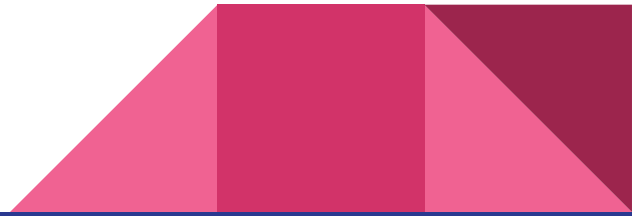


# System Assumptions

- System Type - Closed System
- Each user issues a fixed number of requests.
- Number of cores: 4
- Number of Maximum Threads per core: 4
- Request Buffer Size: 500
- On time-out, requests are retried. There is no limit for retries.
- Requests are dropped only if buffer is empty. User retries for them after timeout.
- Thread-to-Core Affinity
- Thread per request model



# Constants User inputs and Enums

**Constants**-
- Max_buffer_Size
- Max_thread_count
- Conext_switch_time
- Max_Request_Generated

**Users Inputs** –
- Mean_interarrival,
- Mean_service
- Number_of_users

**Scheduling Policy** ***(Enum)***
- FCFS (1)
- Round Robin (2)

**Server Status** ***(Enum)***
- Idle (1)
- Busy (2)

**Event Types** ***(Enum)***
- Arrival (1)
- Departure (2)
- Context_Switch_In (3)

**Distribution Type** ***(Enum)***
- Exponential (1)
- Uniform (2)
- Constant (3)

# Classes

**Service_time**

- *Attributes:*
  - typeOfDistribution(Enum Distribution type)
- *Methods:*
  - getServiceTime() /*Generation function{describes the distribution}*/

**Timeout**

- *Attributes:*
  - constantTime (double)
  - typeOfDistribution(Enum Distribution type)
- *Methods:*
  - getTimeoutTime() /*Generation function{describes the distribution}*/

# Classes

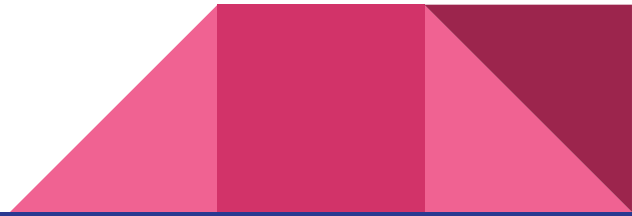
**Event**

- Attributes:
  - arrival_time (double)
  - timeout(double)
  - serviceTime
  - core (int)
  - thread(int)
  - response_count
- Methods:
  - getRandomThinkTime()/*random value chosen in range [4,10]*/
  - getRemainingServiceTime()

# Classes

## Core

- *Attributes:*
  - threads [Max Thread Count] (Event Object List)
  - status (int) {Server Status}
  - thread_busy_count (int)
- *Methods*:
  - GetCoreStatus()
  - setCoreStatus()
  - addToThread()
  - removeFromThread()
  - getBusyThreadCount()
  - setBusyThreadCount()



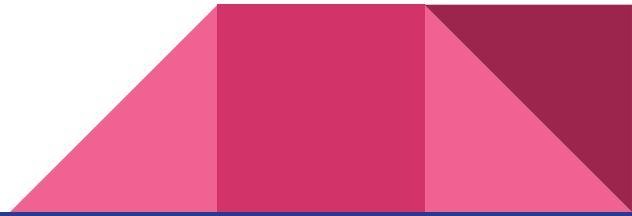
# Classes

**Scheduler**

- *Attributes:*
  - Type (int) {Scheduling policy}
  - Context_switch_time (double)

**Server**

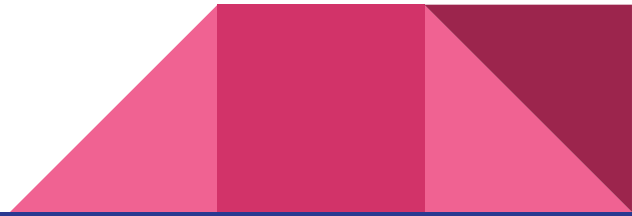
- *Attributes:*
  - Core Object [4];
  - service_time Object;
  - Scheduler Object;
  - {Waiting Buffer} Event Obj queue [Max buffer size]  (shared among all cores)
- *Methods:*
  - getNextEventFromBuffer()
  - getServerStatus()
  - setServerStatus()
  - getCoreObj()



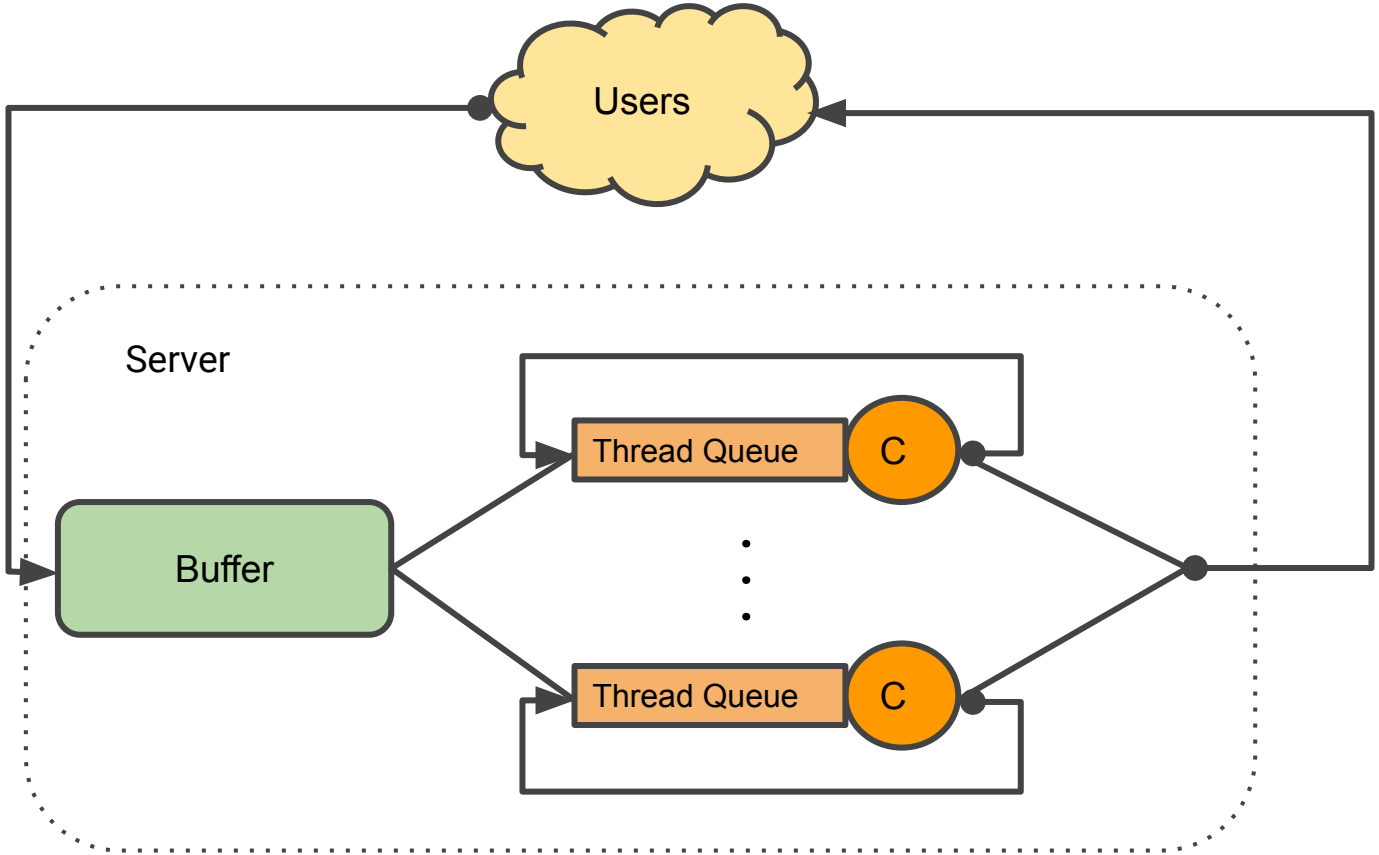
# Classes

**Event Handler**

- *Attributes*:
  - Server Obj
  - timing_next_event[Max_event_count] (a  priority queue of tuples <event_time, event obj> prioritized on event_time)
  - Timeout Obj
- *Methods*:
  - getNextEvent()
  - manageEvent()
  - Arrive()
  - Depart()
  - getServerObj()
  - setEvent()



# System Architecture


Users
Server
Thread Queue
C
Buffer
Thread Queue
C

# Code Highlights

# Code Highlights

## Server Log Output

Trace.txt

```
88.3154    [A A A I ]  EMPTY    Cntx Swtch In     88.4154
==========================================================================
88.4154    [A A A I ]  EMPTY    Departure         88.4806
==========================================================================
88.4806    [A I A I ]  EMPTY    Arrival           88.7719
==========================================================================
88.7719    [A A A I ]  EMPTY    Departure         88.787
==========================================================================
88.787     [I A A I ]  EMPTY    Cntx Swtch In     88.8719
==========================================================================
88.8719    [I A A I ]  EMPTY    Cntx Swtch Out    89.3719
==========================================================================
89.3719    [I A A I ]  EMPTY    Cntx Swtch In     89.4719
==========================================================================
89.4719    [I A A I ]  EMPTY    Departure         89.7606
==========================================================================
89.7606    [I A I I ]  EMPTY    Cntx Swtch Out    89.9719
==========================================================================
89.9719    [I A I I ]  EMPTY    Cntx Swtch In     90.0719
==========================================================================
90.0719    [I A I I ]  EMPTY    Departure         90.953
==========================================================================
90.953     [I I I I ]  EMPTY    Arrival           91.2877
==========================================================================
91.2877    [A I I I ]  EMPTY    Cntx Swtch In     91.3877
==========================================================================
91.3877    [A I I I ]  EMPTY    Arrival           91.4158
==========================================================================
91.4158    [A A I I ]  EMPTY    Cntx Swtch In     91.5158
==========================================================================
```

## EventHandler ManageEvent

```
void EventHandler::manageEvent(Event event){

    switch (event.type)
    {
     case ARRIVAL:
         this->arrive(event);
         break;

     case DEPARTURE:
         this->depart(event);
         break;

     case CONTEXTSWITCHIN:
         contextSwitchIn(event);
         break;

     case CONTEXTSWITCHOUT:
         contextSwitchOut(event);
         break;

     default:
         break;
    }
}
```

# Simulation Experiments and Results

# Experiments Performed

- The simulation was run multiple times for random values of service times, timeout times, and think times with the same mean for the same number of users.
- The mean of all the runs is considered.
- The above process was repeated for different number of users.
- Response times, CPU utilization, throughput, and request drops are plotted.
- Confidence interval is also plotted for response time to get a clear idea.

# Comparison With Measurement Data

# System Configuration :

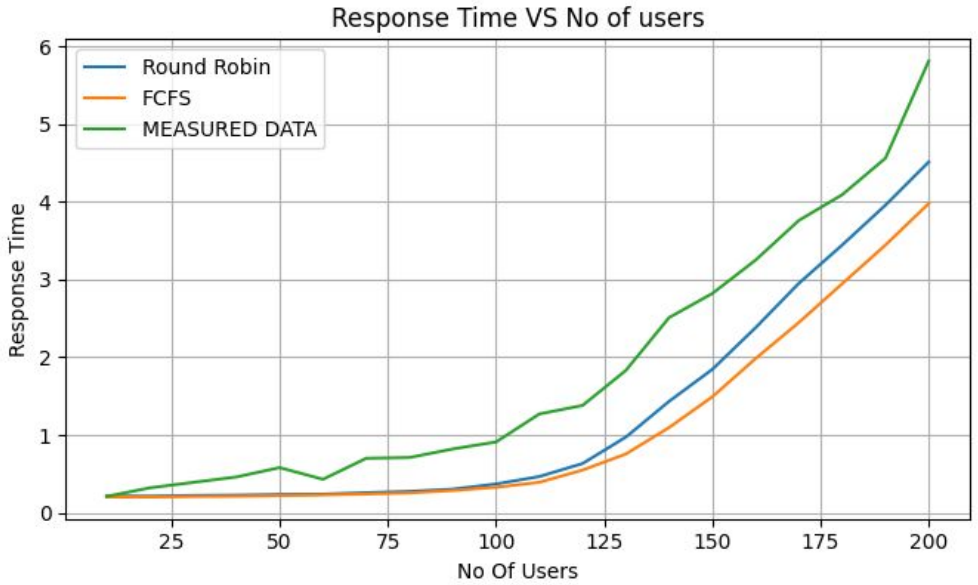
1. Number of Cores: 4
2. Number of Threads per Core: 1
3. Mean Service Time: Exponential (Mean: 0.2 sec)
4. Mean Timeout Time: 50 sec + Exponential (Mean : 5 sec)
5. Context Switch Time (Only for Round-Robin): 0.1 sec
6. Time Quantum (Only for Round-Robin): 0.5 sec

# Experiments Performed

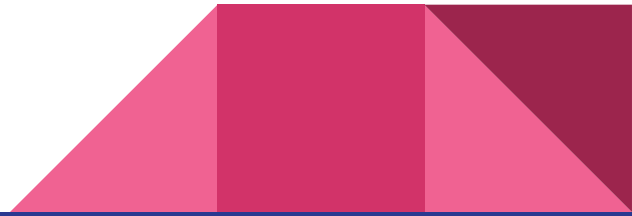
- To compare the simulation outputs with the real system, we plotted values obtained from measurement analysis of the apache server and our simulation, for the same configurations.
- Response time, throughput, and CPU utilization were compared.
- All the metrics showed great similarity in the apache server and our simulation.

# Response Time Vs Number Of Users

- The graphs of measured values and simulation values show very similar trends.
- Although the response time with the round-robin scheduling policy is more than the FCFS policy for all user values.
- This happens because of the context switching in the round-robin policy.
- The saturation number can be found using the response time graph
- **M* = c + c*(1/service time)*think time**
- **M* = 4 + 4*(1/0.2)*6 = 4 + 4*5*6 = 124**

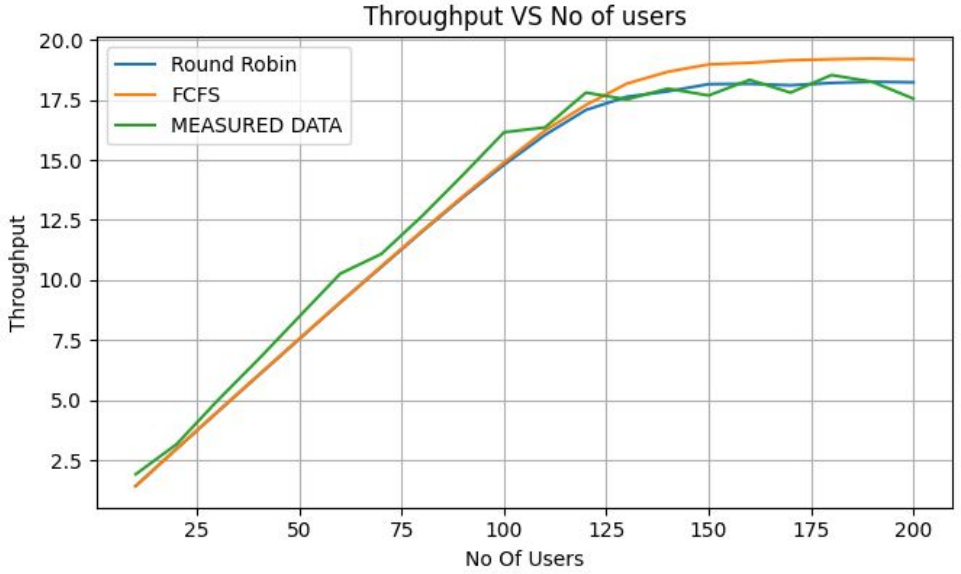


- From graphs, it is clear that the system saturates near 120 users.
- The response time of the measured value is a bit higher than the simulation values. The reason behind this is, in practical systems, there are many more factors affecting the response time that we haven’t modeled in the simulation.



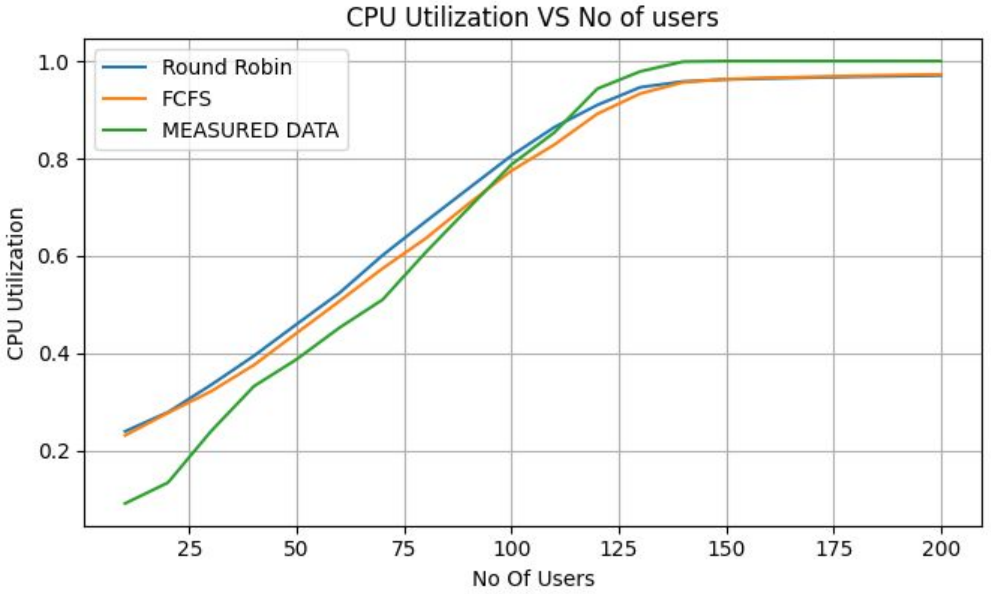
# Throughput Vs Number of Users

- The graphs of measured and simulation values show similar trends.
- The throughput increases initially and saturates at a value of 18 req/sec for round robin and measured values.
- For FCFS system throughput reaches 19 req/sec.
- The system saturates around 125 users.



# CPU Utilization Vs Number of Users

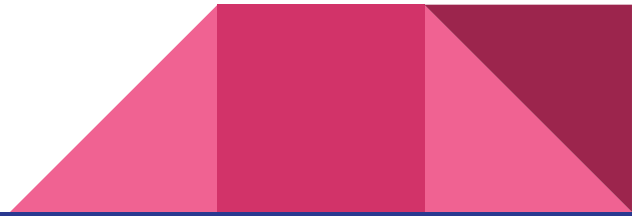
- The graphs of measured and simulation values show similar trends.
- The utilization reaches the maximum value of 1, around 125 users.
- As context switch time is 0 in this case, even in the case of the round-robin, utilization reaches up to 100%.



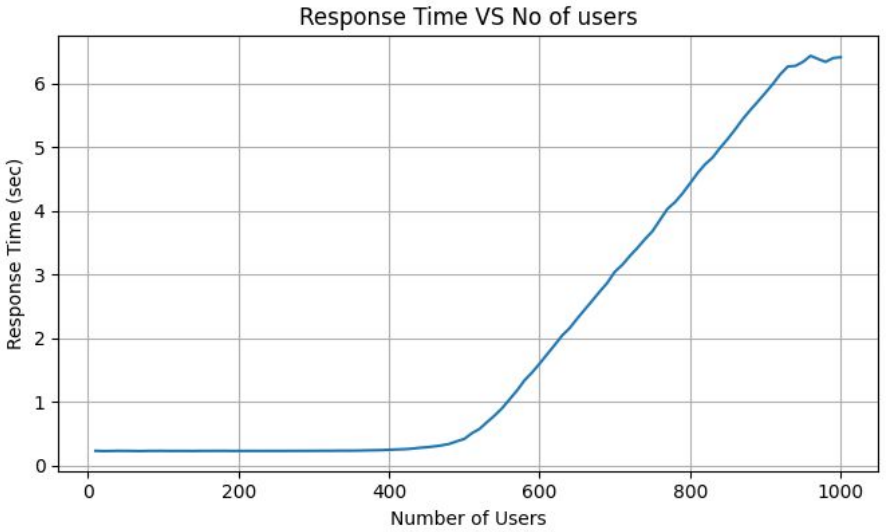
# Multithreaded Web Server Simulation

# System Configuration

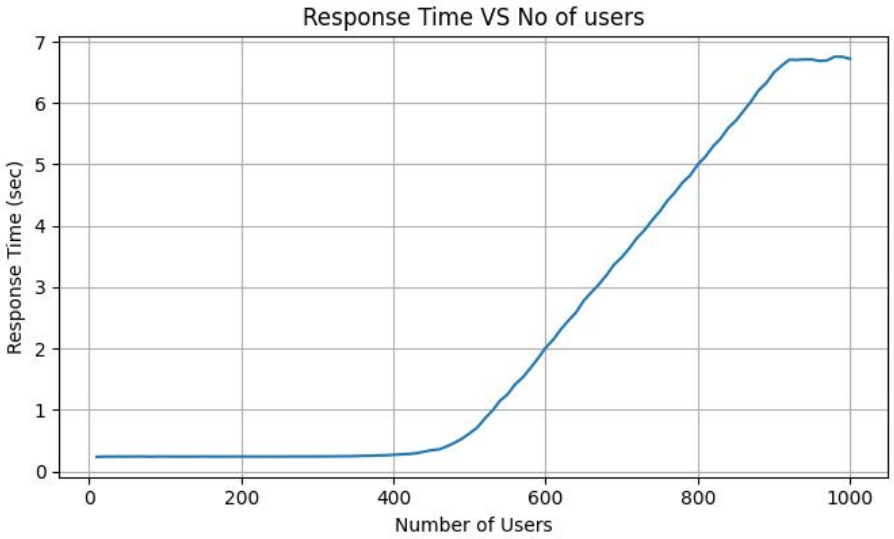
1. Number of Cores: 4
2. Number of Threads per Core: 4
3. Mean Service Time: Exponential (Mean: 0.25 sec)
4. Mean Timeout Time: 50 sec + Exponential (Mean: 5sec)
5. Context Switch Time (Only for Round-Robin): 0.01sec
6. Time Quantum (Only for Round-Robin): 0.5 sec



# Response Time Vs Number of Users

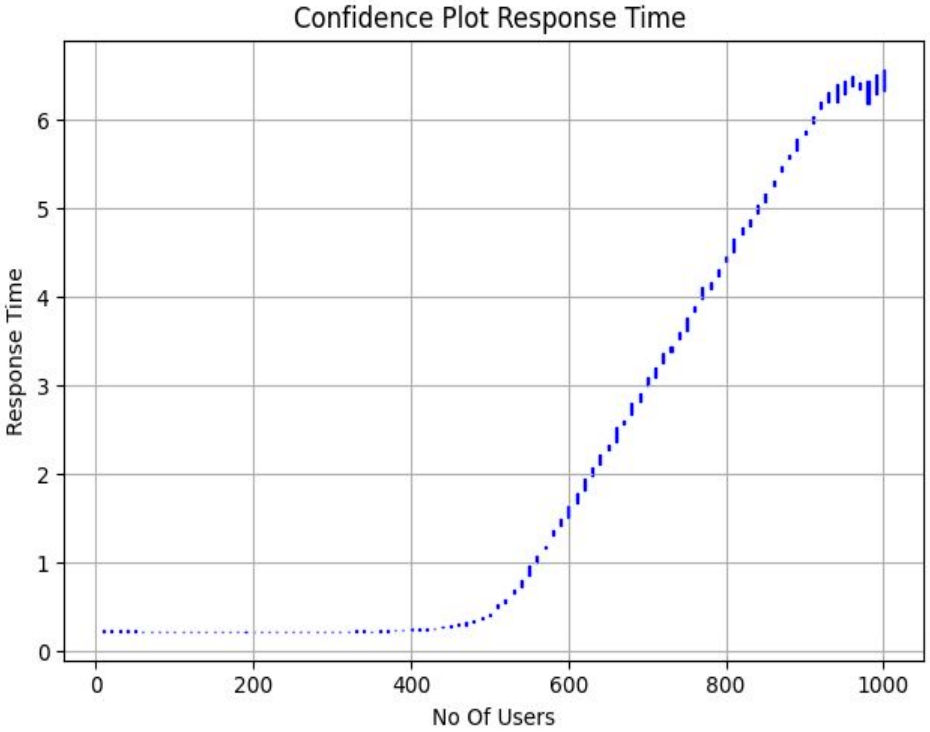



FCFS




Round Robin

# Confidence Interval Graph for Response Time

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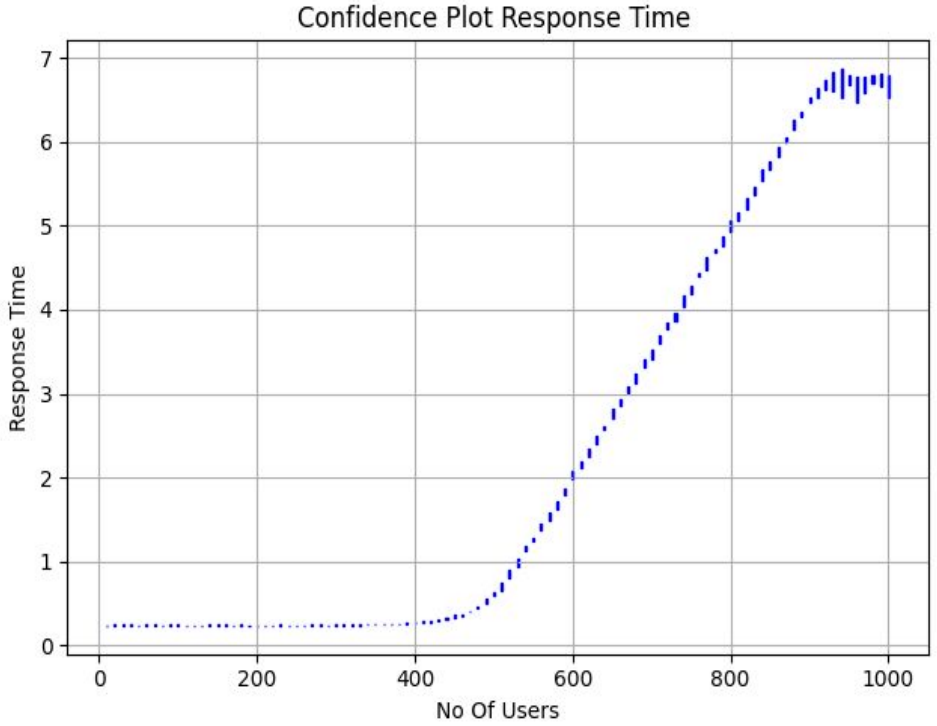
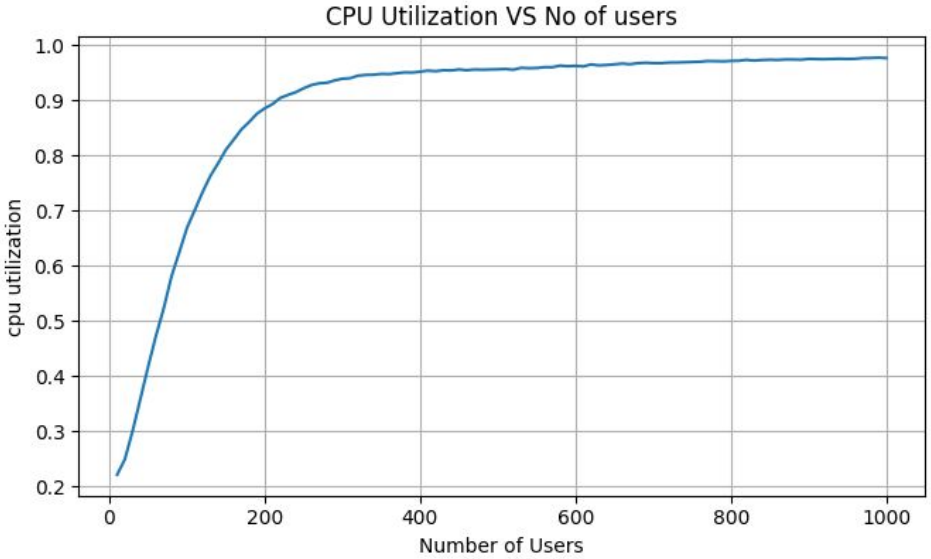



Round Robin

# CPU Utilization Vs Number Of Users

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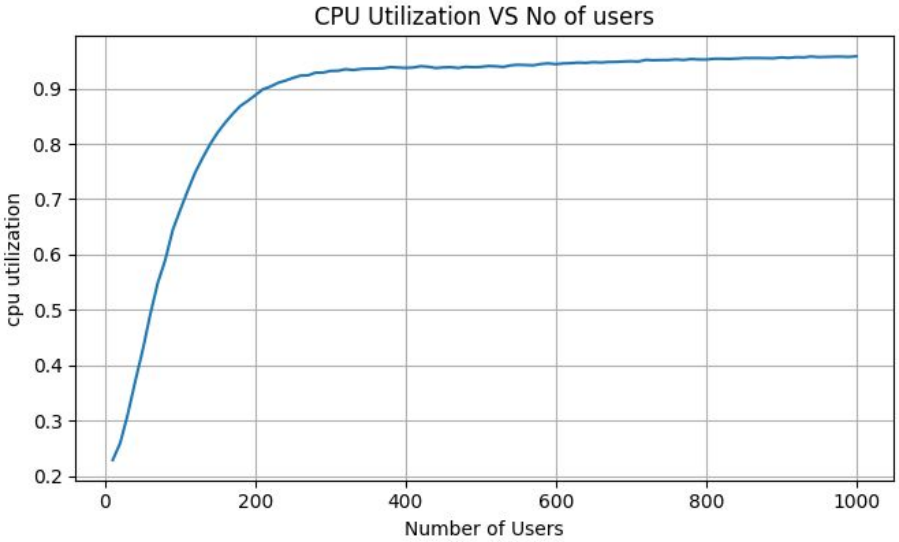
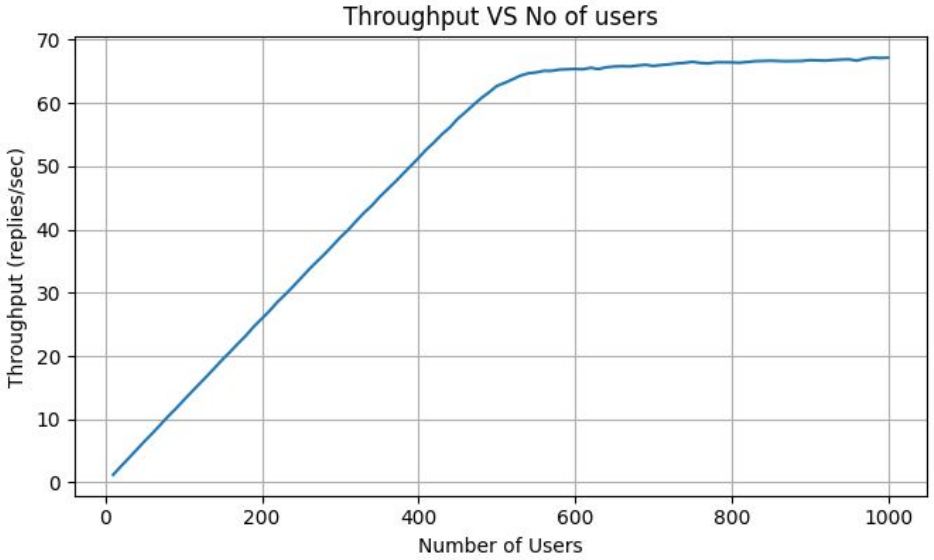



Round Robin

# Throughput Vs Number Of Users

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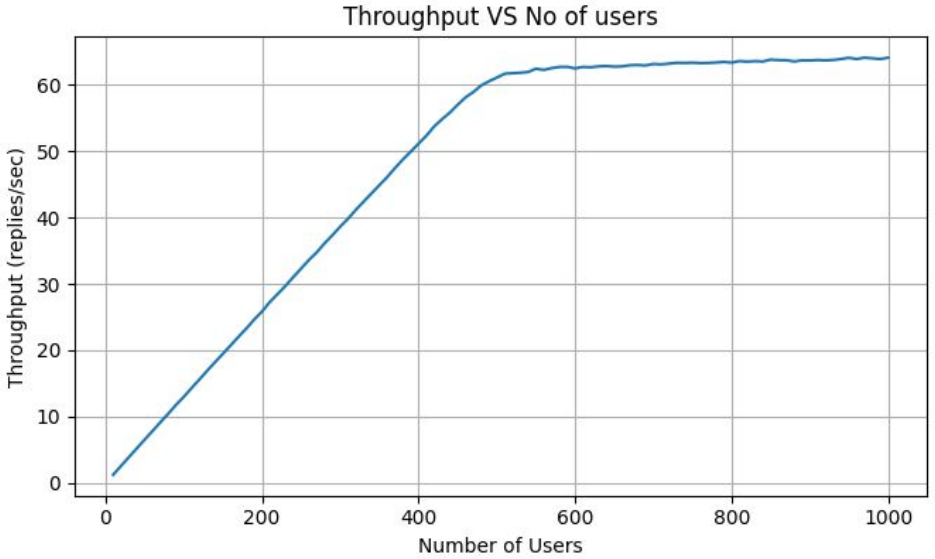
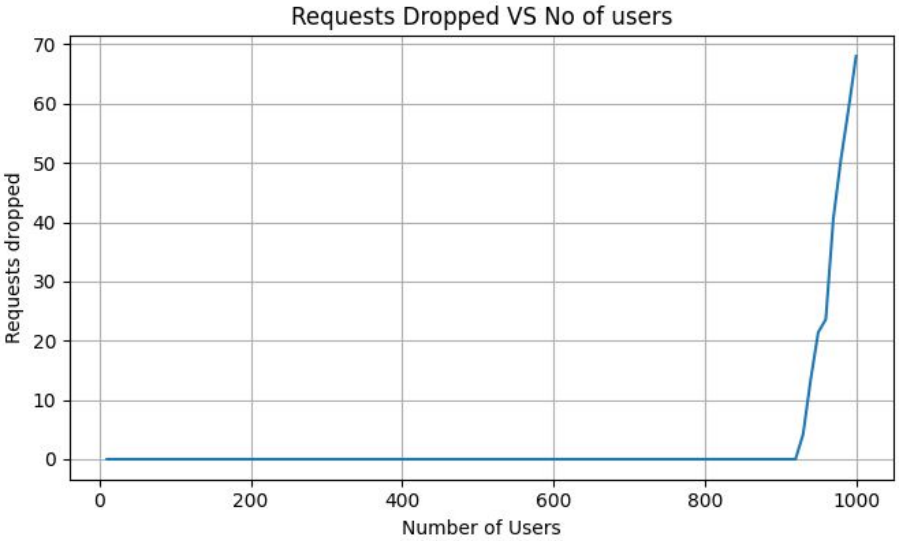



Round Robin

# Requests Drops Vs Number Of Users

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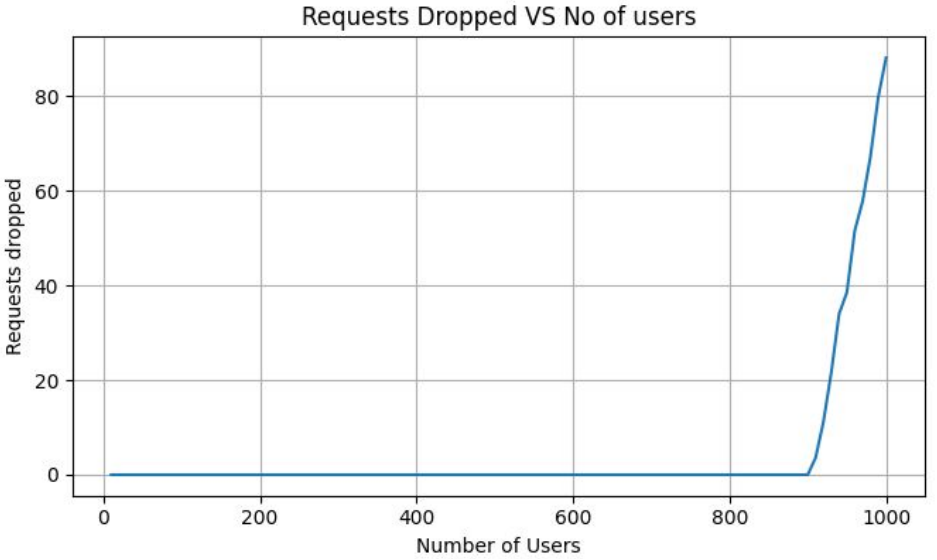



Round Robin

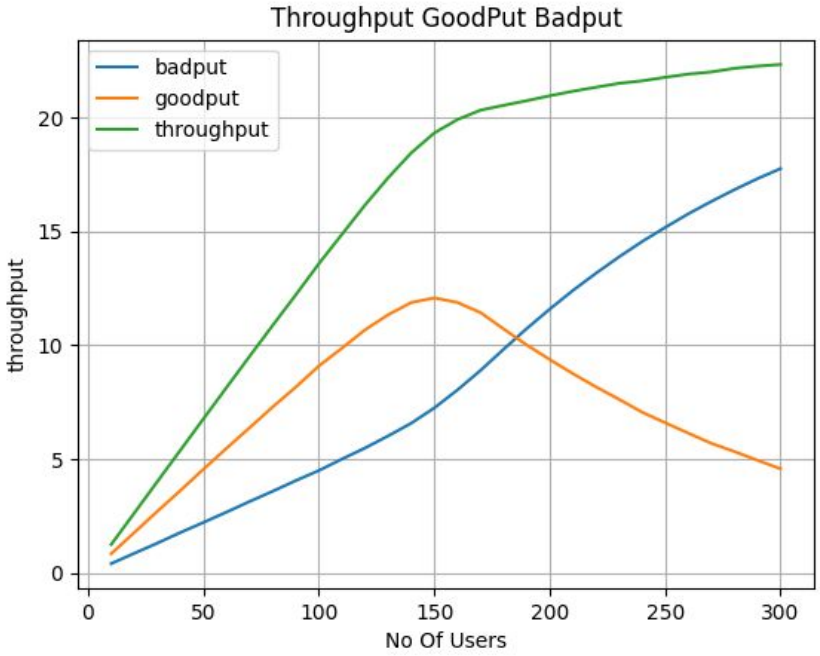
# Curiosity Experiment 1 : Decreased Timeout Value

# System Configuration :

1. Number of Cores: 4
2. Number of Threads per Core: 1
3. Mean Service Time: Exponential (Mean: 0.25 sec)
4. Mean Timeout Time: 5 sec + Exponential (Mean : 5 sec)
5. Context Switch Time (Only for Round-Robin): 0.01 sec
6. Time Quantum (Only for Round-Robin): 0.5 sec

# Throughput, Goodput, Bad-put Comparison

- Experiments were conducted to check the effect of timeout time.
- The graph highlights the effects on throughput, goodput, and bad-put when minimum timeout time is reduced.
- With the decrease in timeout time, bad-put increased after a certain number of users.
- This happens because more and more requests timeout, increasing retries.



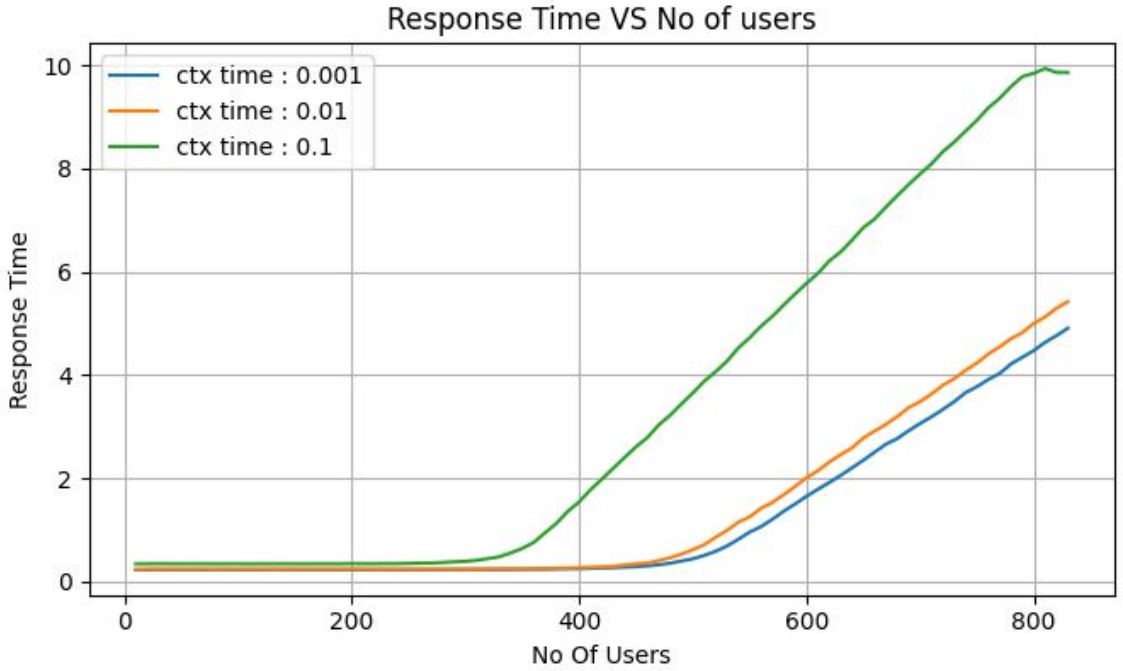
# Curiosity Experiment 2 : Context Switch Time Variation

# System Configuration :

1. Number of Cores: 4
2. Number of Threads per Core: 4
3. Mean Service Time: Exponential (Mean: 0.25 sec)
4. Mean Timeout Time: 50 sec + Exponential (Mean : 5 sec)
5. Context Switch Time (Only for Round-Robin): 0.001sec, 0.01 sec , 0.1sec
6. Time Quantum (Only for Round-Robin): 0.5 sec

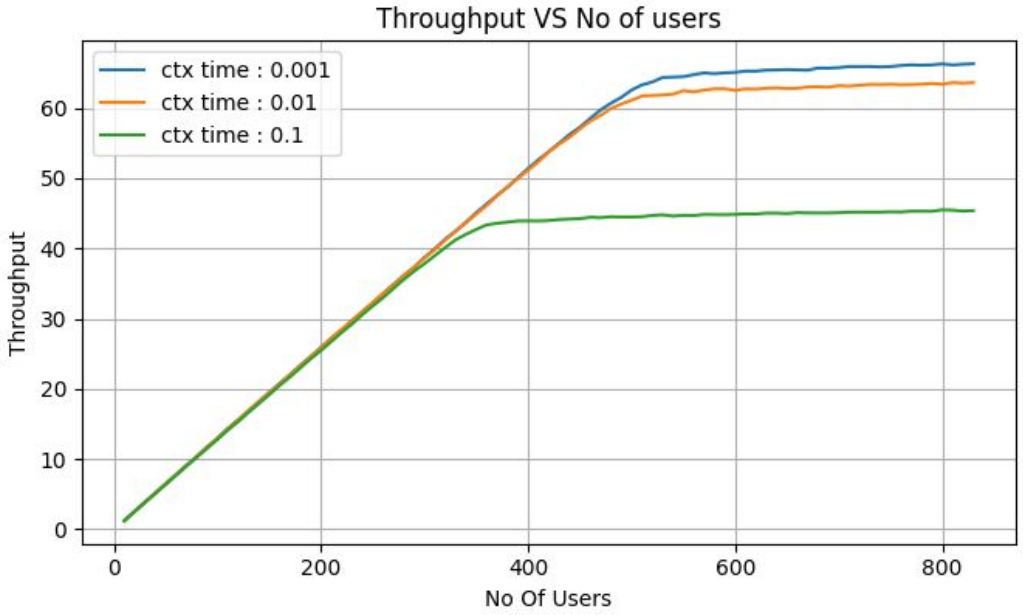
# Response time

- The graph shows the effect of context switch time on response times.
- As the context switch time increases, the response time also increases.
- The context switch is an overhead for the server. The increase in context switch time increases the overhead for each request, increasing the response time.



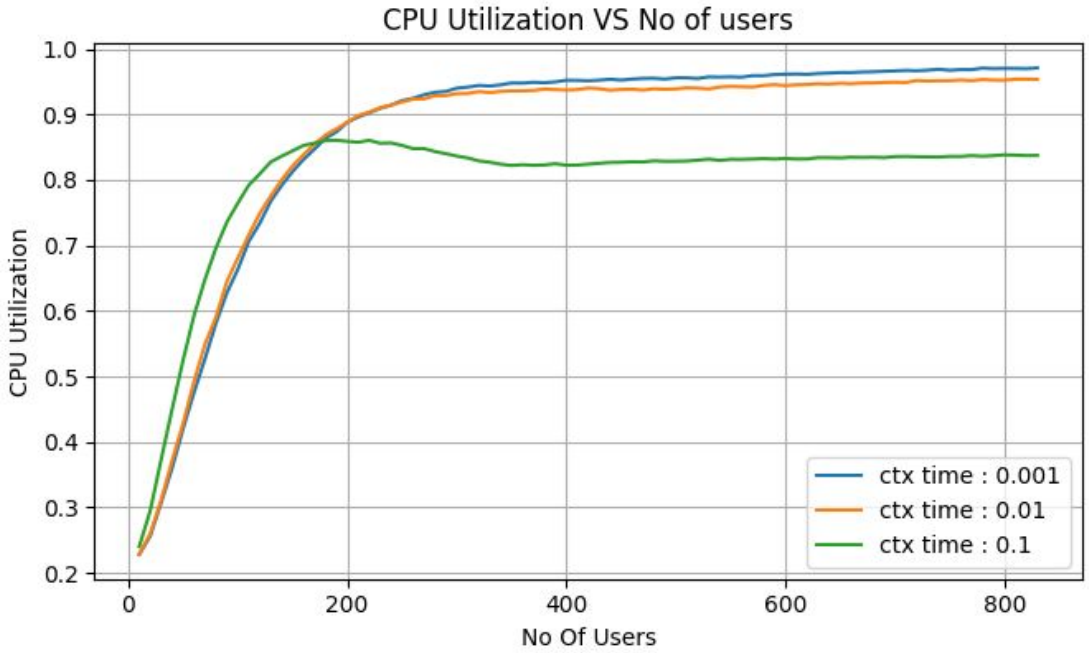
# Throughput

- Contrary to response time, throughput decreases when context switch time increases.
- The reason is the same. Context switching is an overhead for the server, so the time spent in context switching is not a useful time. So, because of more context switching time, fewer overall requests are processed in the same amount of time resulting in less throughput.



# Utilization

- Similar to throughput, utilization also decreases with an increase in context switch time.
- As we don’t consider the context switching time to be useful, we consider the CPU to be idle for that time.
- Utilization is defined as the fraction of time the CPU is busy.
- As context switching time increases idle time of CPU. More context switch time decreases utilization.



# Conclusion

- We implemented a web server simulation program and analysed it using the metrics like throughput, response time, CPU utilization and request drops.
- We also compared the performance with measurements we got from apache server analysis. The comparison showed great similarity in both the systems.
- We also performed some experiments to check the effect of timeouts and context switch times on performance of the web server.
- On decreasing the minimum timeout value, the bad-put increased after some number of users.
- On increasing the context switch time, response time increased while the throughput and CPU utilisation decreased.